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**Wilson**

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(54) **SYSTEM AND METHOD FOR ADAPTIVE APPLICATION OF AUTHENTICATION POLICIES**

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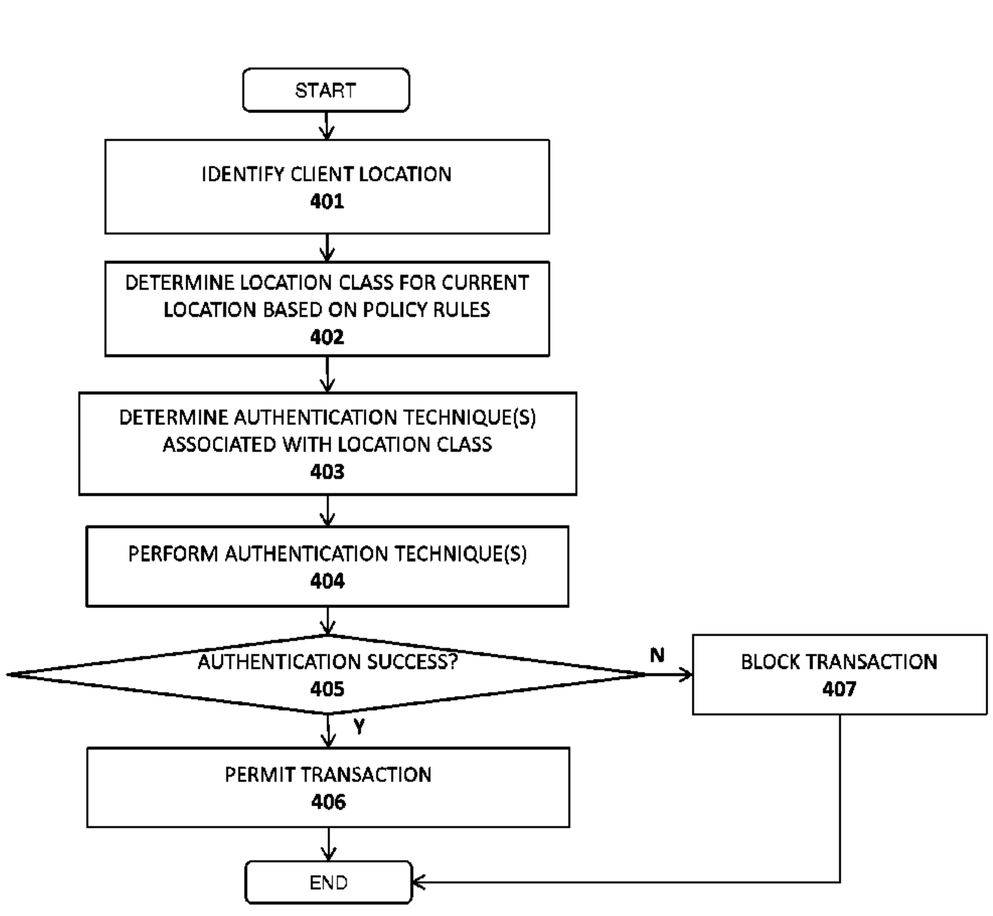
(57) **ABSTRACT**

A system, apparatus, method, and machine readable medium are described for adaptively implementing an authentication policy. For example, one embodiment of a method comprises: detecting a user of a client attempting to perform a current interaction with a relying party; and responsively identifying a first interaction class for the current interaction based on variables associated with the current interaction and implementing a set of one or more authentication rules associated with the first interaction class.

**28 Claims, 11 Drawing Sheets**



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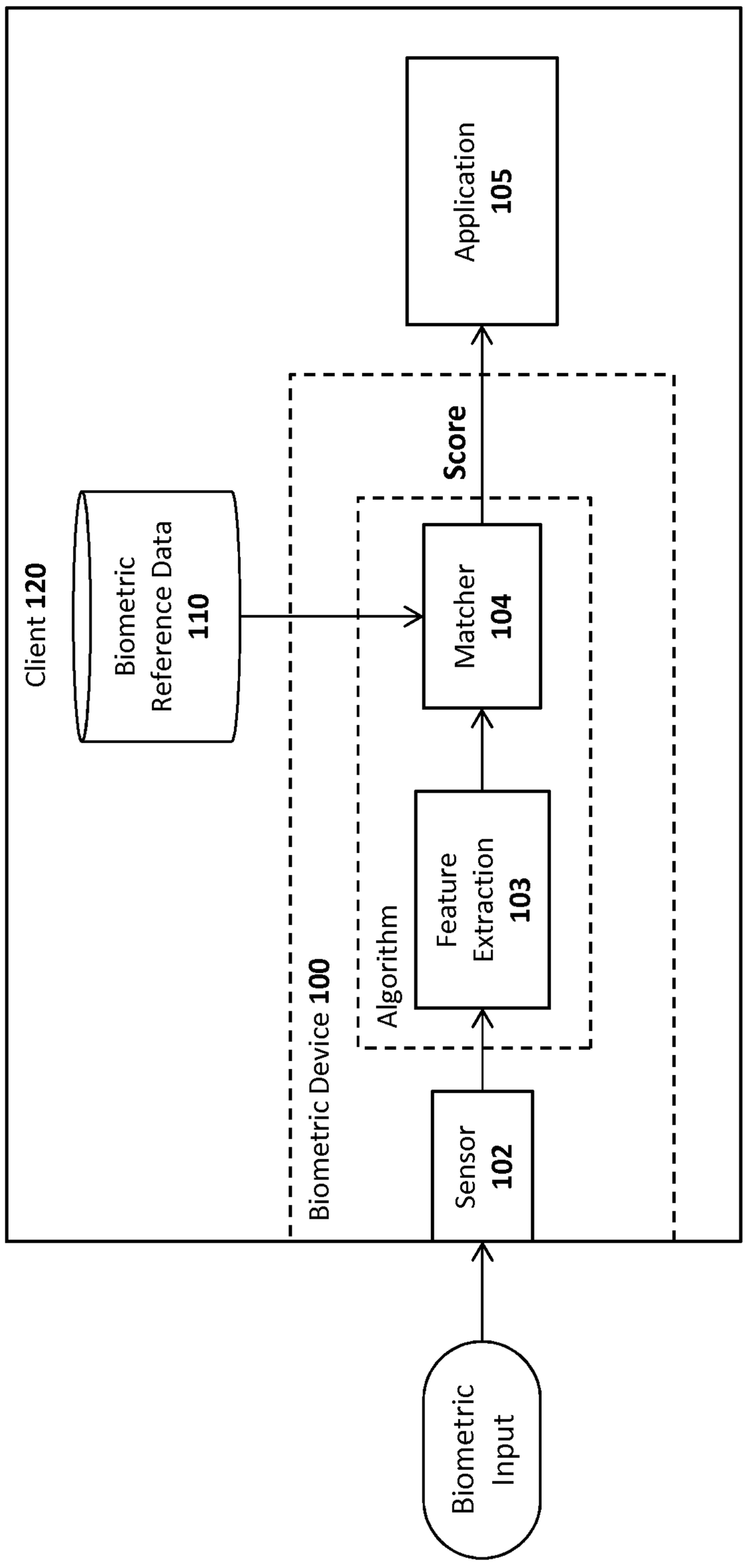


FIG. 1
(prior art)

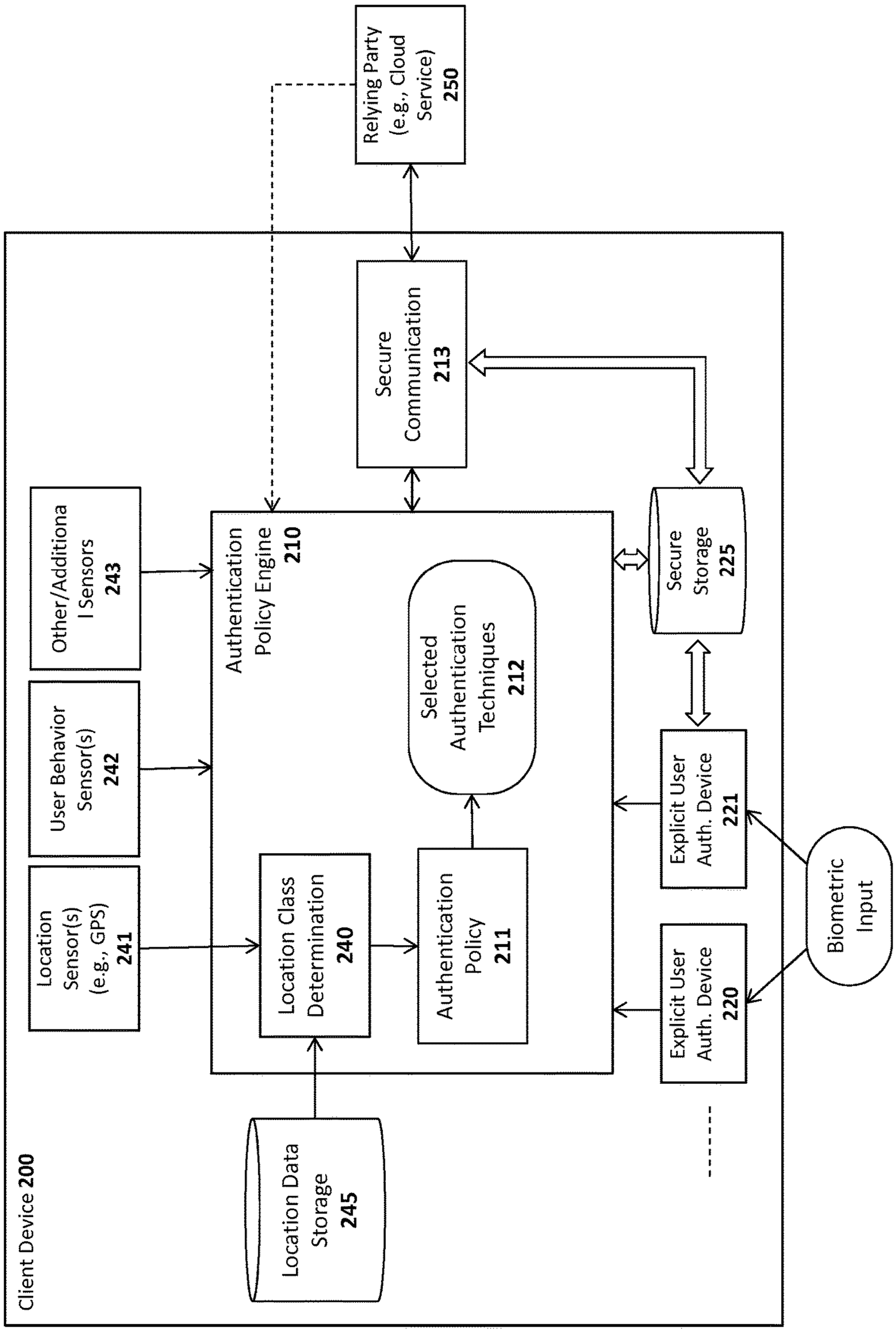
Relying Party (e.g., Cloud Service) 250
Secure Communication 213
Client Device 200
Authentication Policy Engine 210
Other/Additional Sensors 243
User Behavior Sensor(s) 242
Location Sensor(s) (e.g., GPS) 241
Location Class Determination 240
Authentication Policy 211
Selected Authentication Techniques 212
Secure Storage 225
Explicit User Auth. Device 221
Explicit User Auth. Device 220
Biometric Input
Location Data Storage 245

FIG. 2

Authentication Policy **211**

| Rule | Location Class | Minimum Authentication Required |
|---|---|---|
| 1 | Location Class 1 | Authentication Technique(s) 1 |
| 2 | Location Class 2 | Authentication Technique (s) 2 |
| 3 | Location Class 3 | Authentication Technique (s) 3 |
| 4 | Location Class 4 | Authentication Technique (s) 4 |
| 5 | Location Class 5 | Authentication Technique (s) 5 |
| ----- | ----- | ----- |

**FIG. 3**

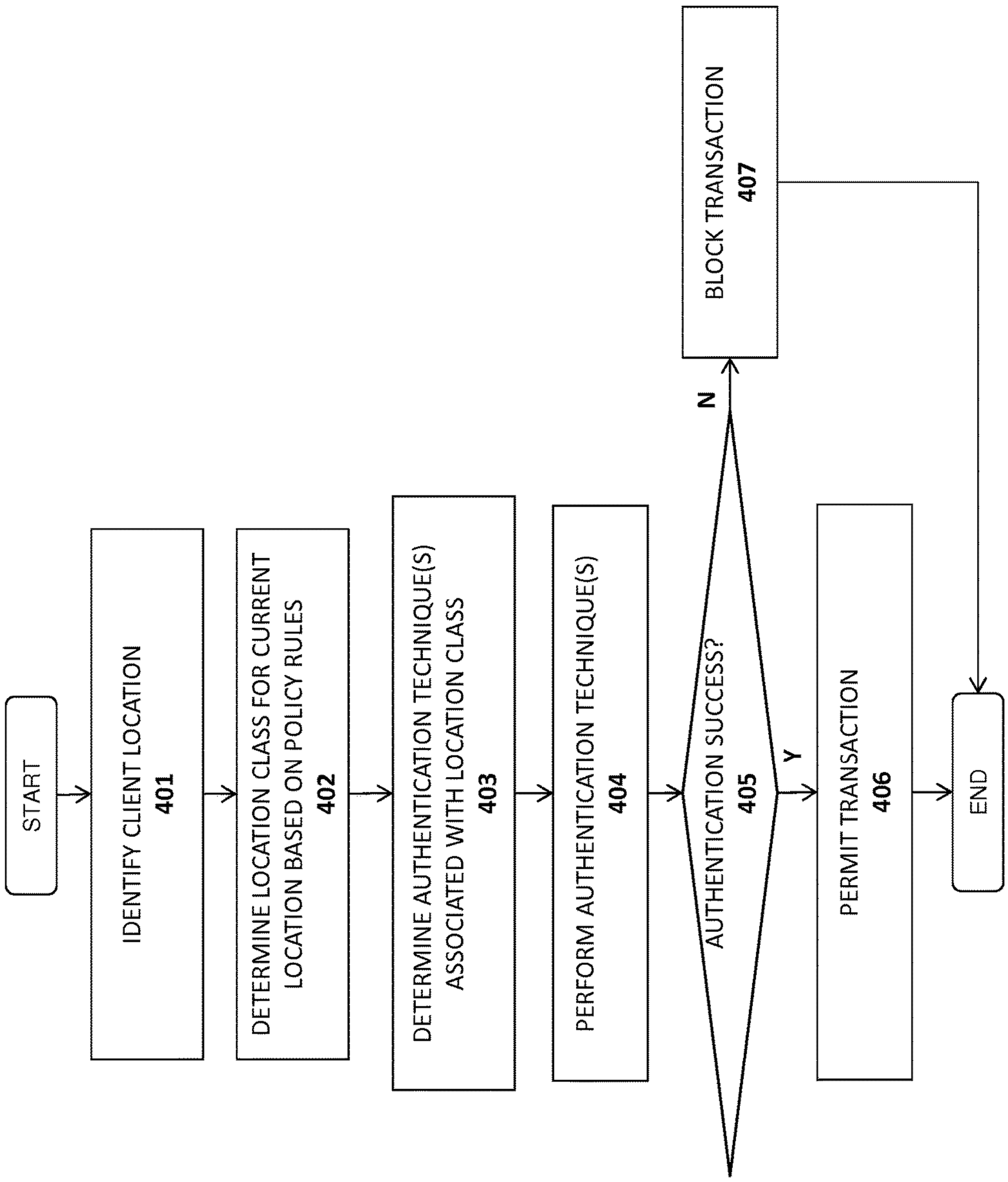
START
IDENTIFY CLIENT LOCATION
401
DETERMINE LOCATION CLASS FOR CURRENT LOCATION BASED ON POLICY RULES
402
DETERMINE AUTHENTICATION TECHNIQUE(S) ASSOCIATED WITH LOCATION CLASS
403
PERFORM AUTHENTICATION TECHNIQUE(S)
404
AUTHENTICATION SUCCESS?
405
N
Y
BLOCK TRANSACTION
407
PERMIT TRANSACTION
406
END

FIG. 4

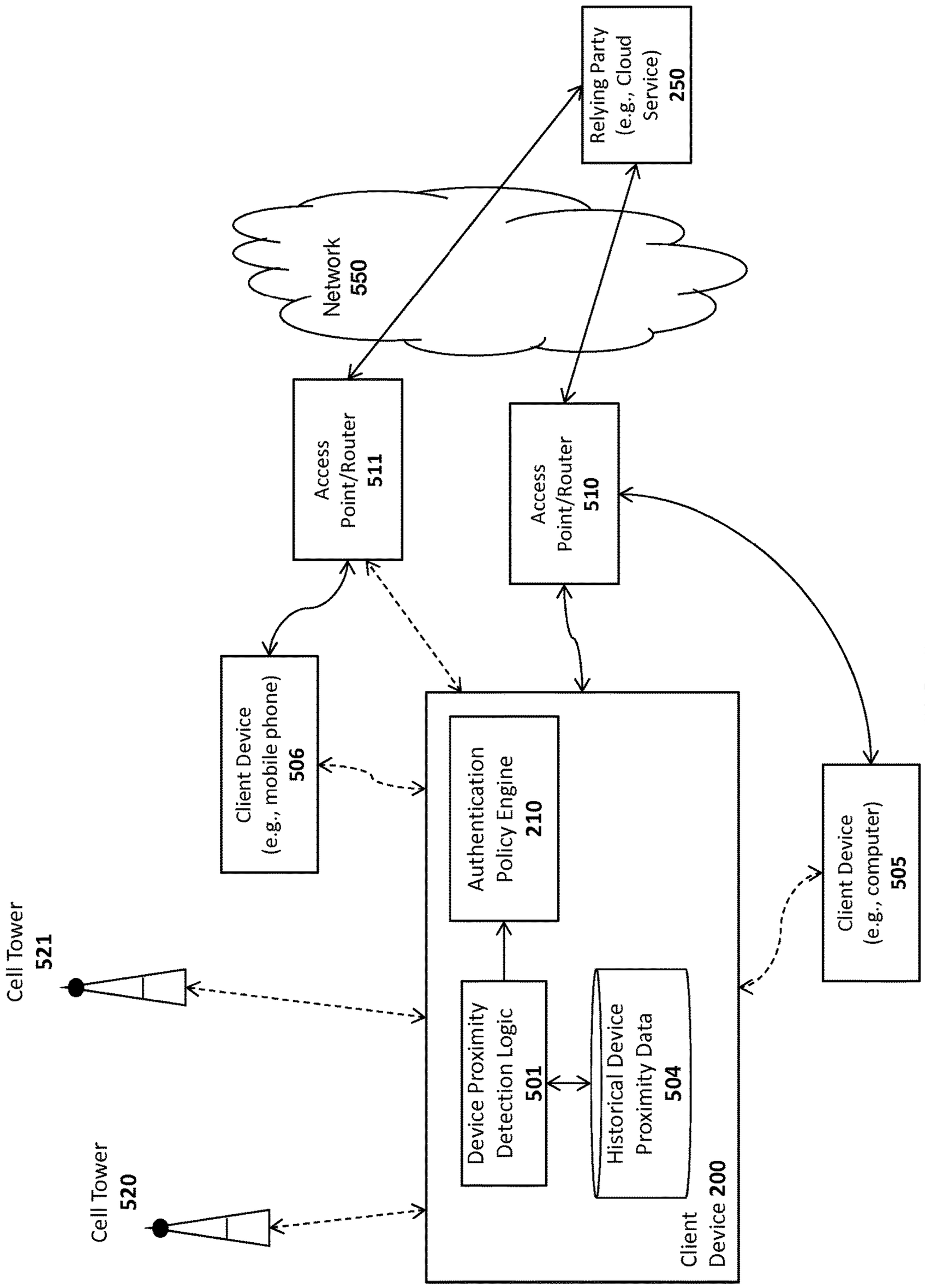
Relying Party (e.g., Cloud Service) 250
Network 550
Access Point/Router 511
Access Point/Router 510
Client Device (e.g., mobile phone) 506
Authentication Policy Engine 210
Client Device (e.g., computer) 505
Cell Tower 521
Cell Tower 520
Device Proximity Detection Logic 501
Historical Device Proximity Data 504
Client Device 200

FIG. 5

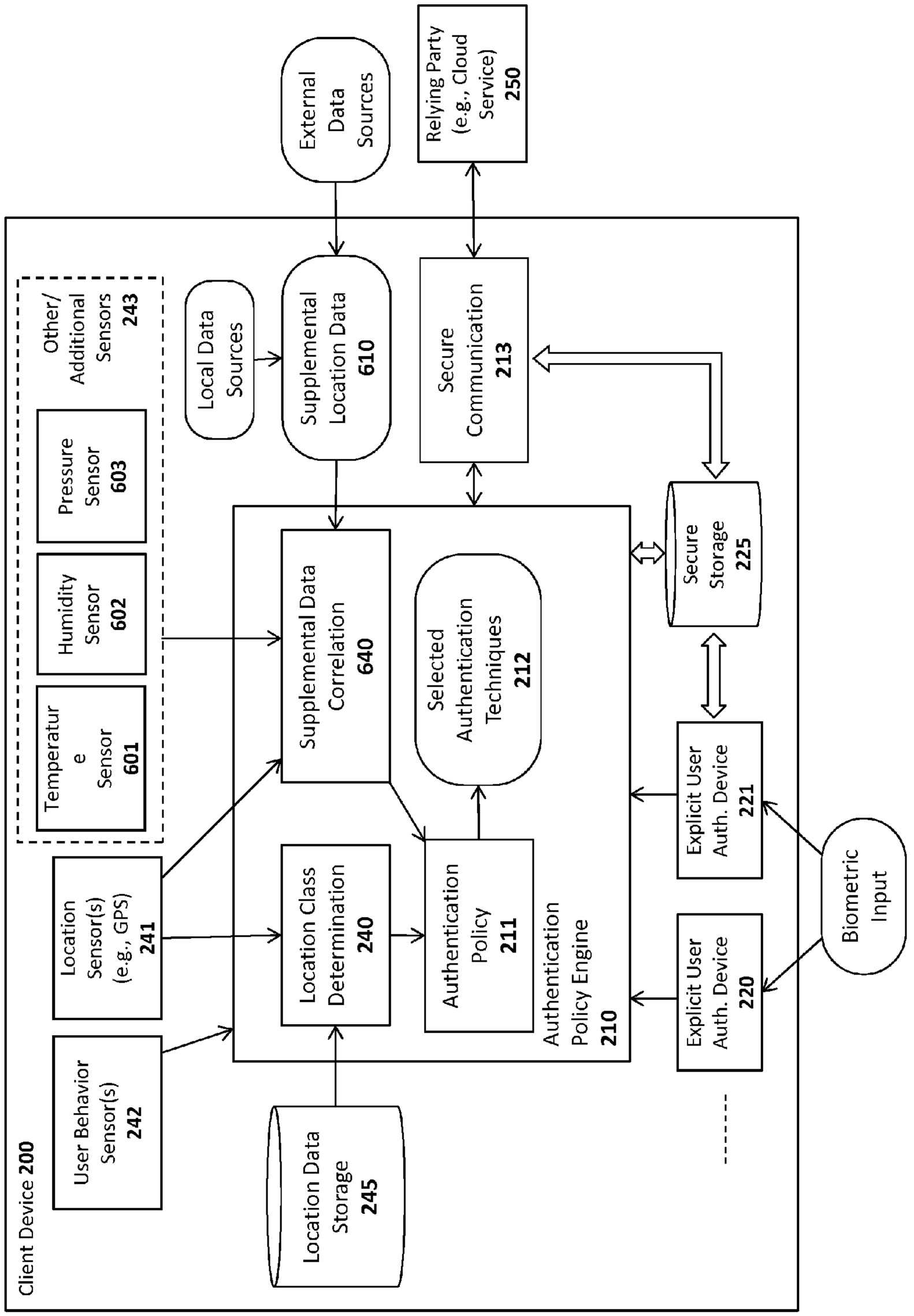
Client Device 200
External Data Sources
Relying Party (e.g., Cloud Service) 250
Local Data Sources
Supplemental Location Data 610
Secure Communication 213
Other/ Additional Sensors 243
Pressure Sensor 603
Humidity Sensor 602
Temperature Sensor 601
Location Sensor(s) (e.g., GPS) 241
User Behavior Sensor(s) 242
Supplemental Data Correlation 640
Selected Authentication Techniques 212
Location Class Determination 240
Authentication Policy 211
Authentication Policy Engine 210
Secure Storage 225
Explicit User Auth. Device 221
Explicit User Auth. Device 220
Biometric Input
Location Data Storage 245

FIG. 6

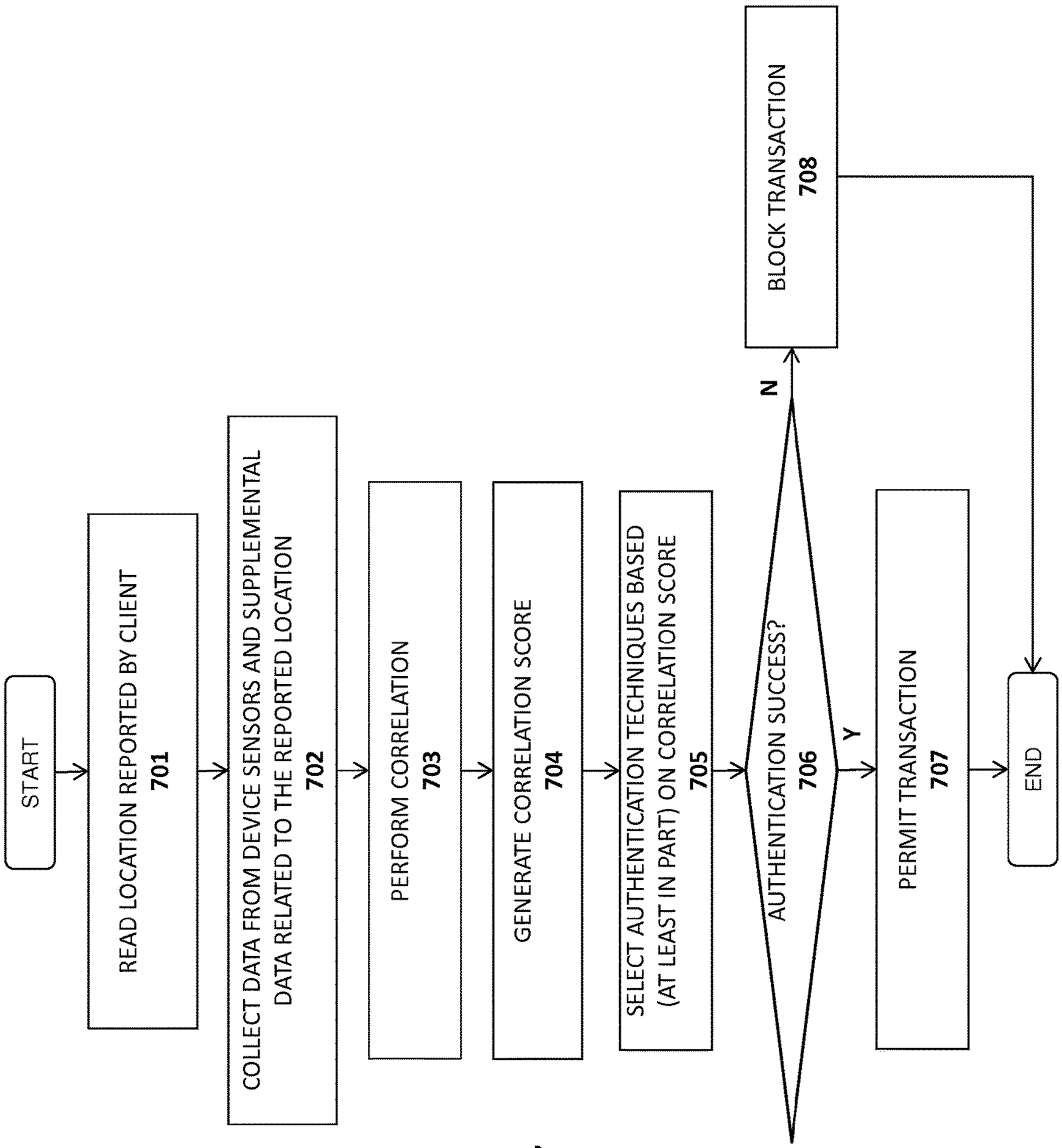
START
READ LOCATION REPORTED BY CLIENT
701
COLLECT DATA FROM DEVICE SENSORS AND SUPPLEMENTAL DATA RELATED TO THE REPORTED LOCATION
702
PERFORM CORRELATION
703
GENERATE CORRELATION SCORE
704
SELECT AUTHENTICATION TECHNIQUES BASED (AT LEAST IN PART) ON CORRELATION SCORE
705
AUTHENTICATION SUCCESS?
706
N
BLOCK TRANSACTION
708
Y
PERMIT TRANSACTION
707
END

FIG. 7

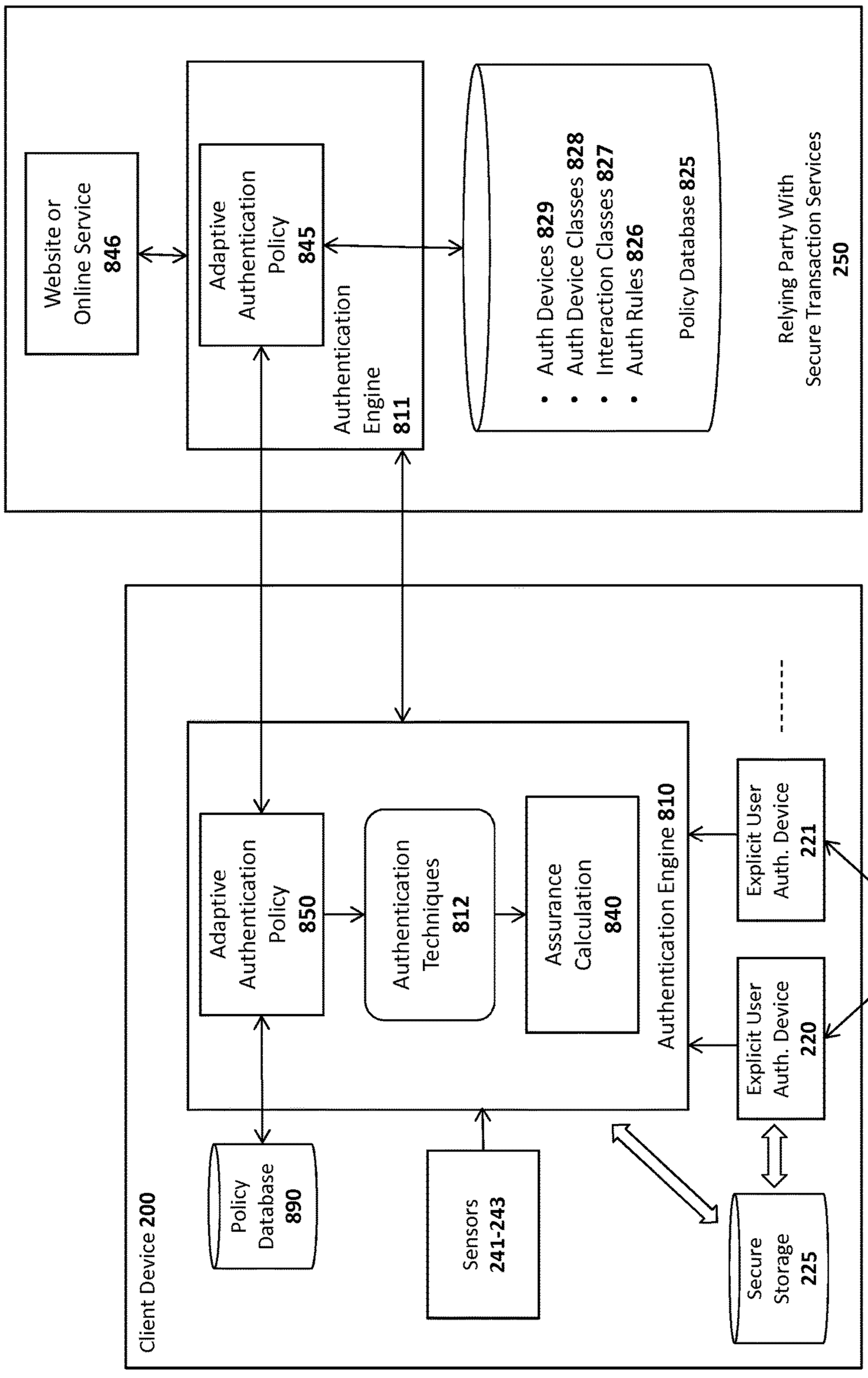
Website or Online Service 846
Adaptive Authentication Policy 845
Authentication Engine 811
Auth Devices 829
Auth Device Classes 828
Interaction Classes 827
Auth Rules 826
Policy Database 825
Relying Party With Secure Transaction Services 250
Client Device 200
Adaptive Authentication Policy 850
Authentication Techniques 812
Assurance Calculation 840
Authentication Engine 810
Explicit User Auth. Device 221
Biometric Input
Policy Database 890
Sensors 241-243
Secure Storage 225

FIG. 8

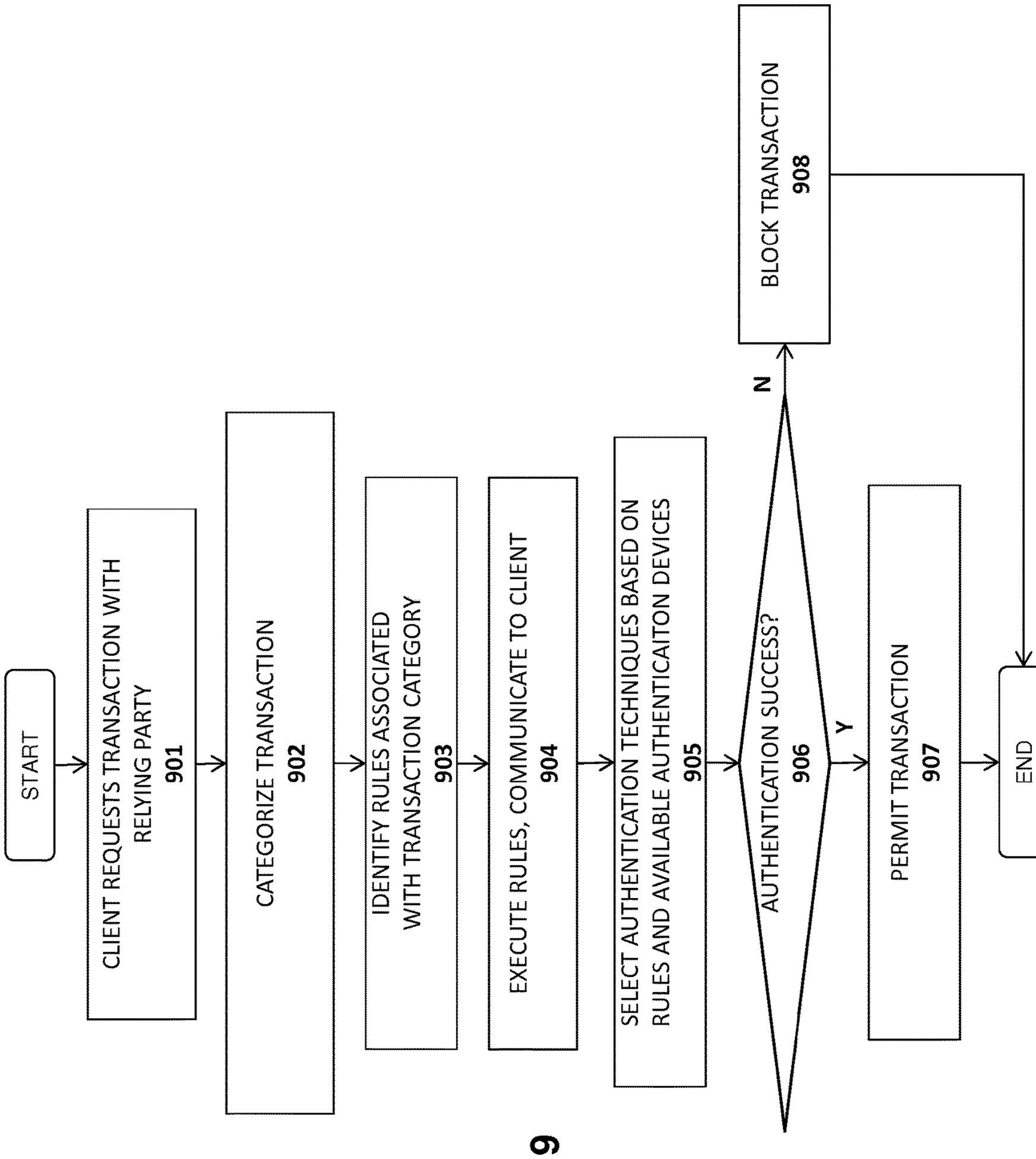
START
CLIENT REQUESTS TRANSACTION WITH RELYING PARTY
901
CATEGORIZE TRANSACTION
902
IDENTIFY RULES ASSOCIATED WITH TRANSACTION CATEGORY
903
EXECUTE RULES, COMMUNICATE TO CLIENT
904
SELECT AUTHENTICATION TECHNIQUES BASED ON RULES AND AVAILABLE AUTHENTICAITON DEVICES
905
AUTHENTICATION SUCCESS?
906
N
BLOCK TRANSACTION
908
Y
PERMIT TRANSACTION
907
END

FIG. 9

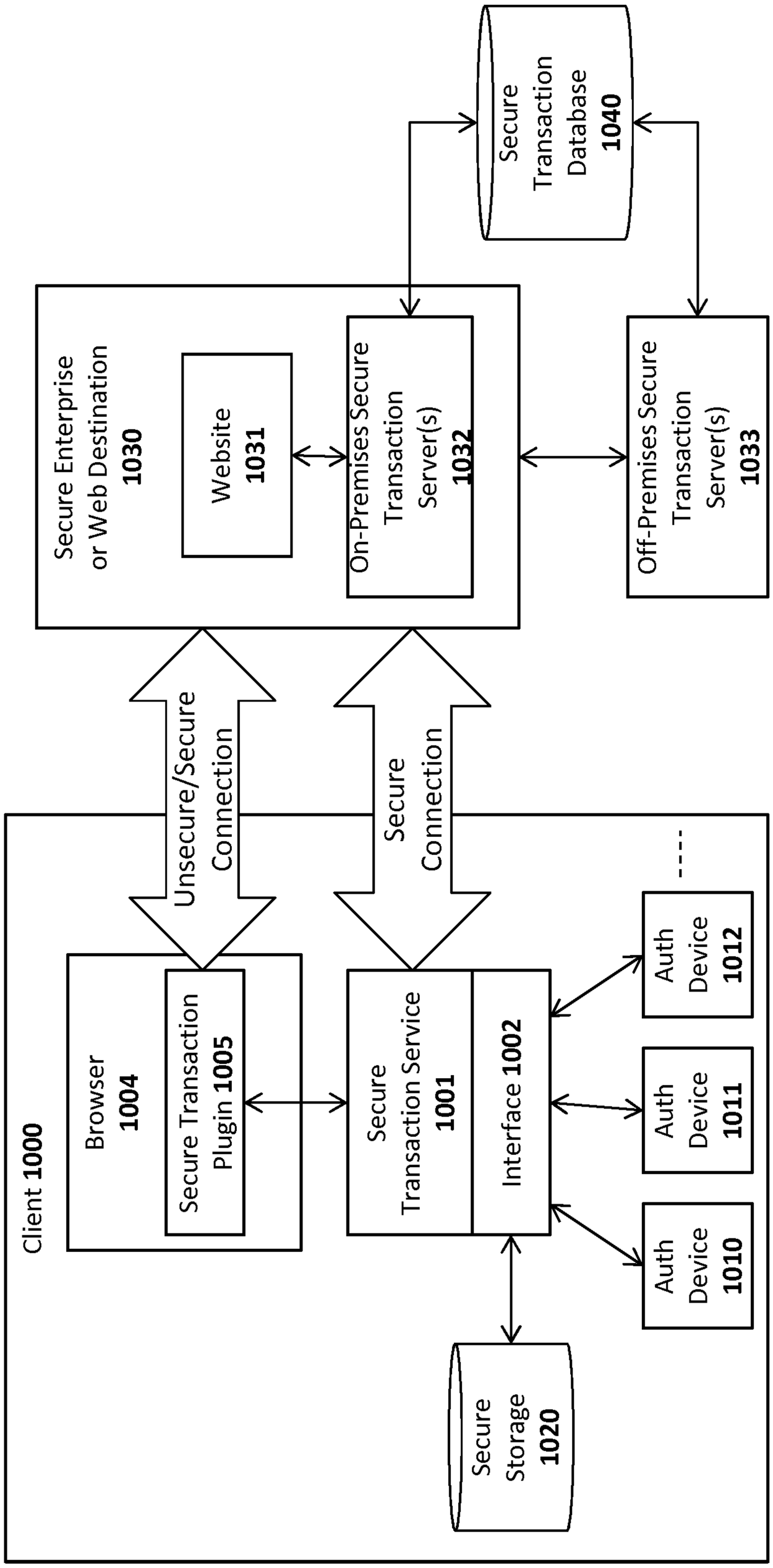
Secure Transaction Database 1040
Secure Enterprise or Web Destination 1030
Website 1031
On-Premises Secure Transaction Server(s) 1032
Off-Premises Secure Transaction Server(s) 1033
Unsecure/Secure Connection
Secure Connection
Client 1000
Browser 1004
Secure Transaction Plugin 1005
Secure Transaction Service 1001
Interface 1002
Auth Device 1012
Auth Device 1011
Auth Device 1010
Secure Storage 1020

FIG. 10A

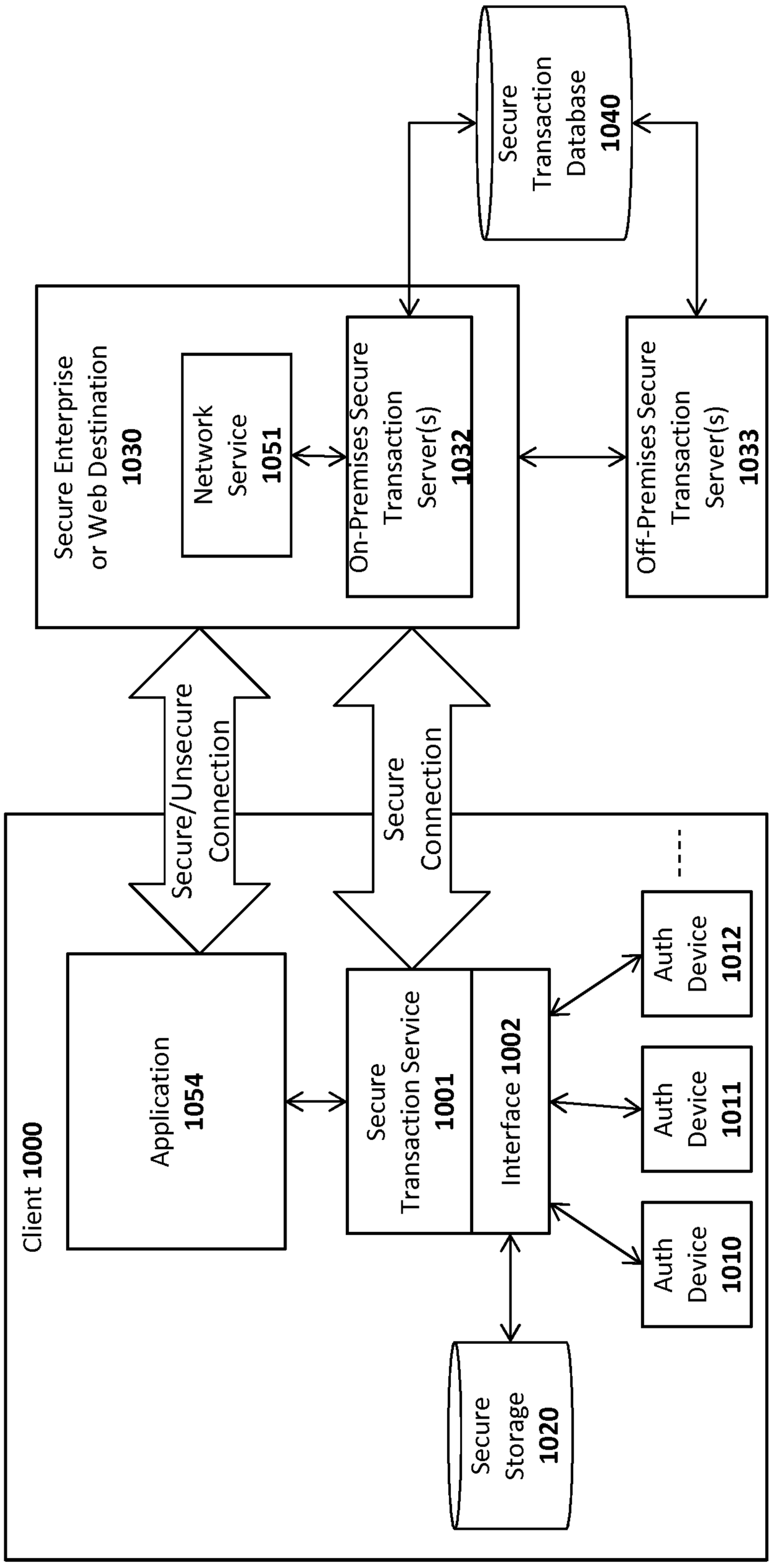
Secure Transaction Database 1040
Secure Enterprise or Web Destination 1030
Network Service 1051
On-Premises Secure Transaction Server(s) 1032
Off-Premises Secure Transaction Server(s) 1033
Secure/Unsecure Connection
Secure Connection
Client 1000
Application 1054
Secure Transaction Service 1001
Interface 1002
Auth Device 1012
Auth Device 1011
Auth Device 1010
Secure Storage 1020

FIG. 10B

# SYSTEM AND METHOD FOR ADAPTIVE APPLICATION OF AUTHENTICATION POLICIES

## CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of and priority to U.S. Provisional Patent Application No. 61/804,568, filed, Mar. 22, 2013, entitled, "Advanced Methods of Authentication And Its Applications".

## BACKGROUND

Field of the Invention

This invention relates generally to the field of data processing systems. More particularly, the invention relates to a system and method for adaptive application of authentication policies.

Description of Related Art

FIG. **1** illustrates an exemplary client **120** with a biometric device **100**. When operated normally, a biometric sensor **102** reads raw biometric data from the user (e.g., capture the user's fingerprint, record the user's voice, snap a photo of the user, etc) and a feature extraction module **103** extracts specified characteristics of the raw biometric data (e.g., focusing on certain regions of the fingerprint, certain facial features, etc). A matcher module **104** compares the extracted features **133** with biometric reference data **110** stored in a secure storage on the client **120** and generates a score based on the similarity between the extracted features and the biometric reference data **110**. The biometric reference data **110** is typically the result of an enrollment process in which the user enrolls a fingerprint, voice sample, image or other biometric data with the device **100**. An application **105** may then use the score to determine whether the authentication was successful (e.g., if the score is above a certain specified threshold).

Systems have been designed for providing secure user authentication over a network using biometric sensors. In such systems, the score generated by the application, and/or other authentication data, may be sent over a network to authenticate the user with a remote server. For example, Patent Application No. 2011/0082801 ("'801 application") describes a framework for user registration and authentication on a network which provides strong authentication (e.g., protection against identity theft and phishing), secure transactions (e.g., protection against "malware in the browser" and "man in the middle" attacks for transactions), and enrollment/management of client authentication tokens (e.g., fingerprint readers, facial recognition devices, smartcards, trusted platform modules, etc).

The assignee of the present application has developed a variety of improvements to the authentication framework described in the '801 application. Some of these improvements are described in the following set of U.S. Patent Applications ("Co-pending Applications"), all filed Dec. 29, 1012, which are assigned to the present assignee and incorporated herein by reference: Ser. No. 13/730,761, Query System and Method to Determine Authentication Capabilities; Ser. No. 13/730,776, System and Method for Efficiently Enrolling, Registering, and Authenticating With Multiple Authentication Devices; Ser. No. 13/730,780, System and Method for Processing Random Challenges Within an Authentication Framework; Ser. No. 13/730,791, System and Method for Implementing Privacy Classes Within an Authentication Framework; Ser. No. 13/730,795, System and Method for Implementing Transaction Signaling Within an Authentication Framework.



Briefly, the Co-Pending applications describe authentication techniques in which a user enrolls with biometric devices of a client to generate biometric template data (e.g., by swiping a finger, snapping a picture, recording a voice, etc); registers the biometric devices with one or more servers over a network (e.g., Websites or other relying parties equipped with secure transaction services as described in the Co-Pending applications); and subsequently authenticates with those servers using data exchanged during the registration process (e.g., encryption keys provisioned into the biometric devices). Once authenticated, the user is permitted to perform one or more online transactions with a Website or other relying party. In the framework described in the Co-Pending applications, sensitive information such as fingerprint data and other data which can be used to uniquely identify the user, may be retained locally on the user's client device (e.g., smartphone, notebook computer, etc) to protect a user's privacy.

For certain classes of transactions, the riskiness associated with the transaction may be inextricably tied to the location where the transaction is being performed. For example, it may be inadvisable to allow a transaction that appears to originate in a restricted country, such as those listed on the US Office of Foreign Asset Control List (e.g., Cuba, Libya, North Korea, etc). In other cases, it may only be desirable to allow a transaction to proceed if a stronger authentication mechanism is used; for example, a transaction undertaken from within the corporation's physical premises may require less authentication than one conducted from a Starbucks located in a remote location where the company does not have operations.

However, reliable location data may not be readily available for a variety of reasons. For example, the end user's device may not have GPS capabilities; the user may be in a location where Wifi triangulation data is unavailable or unreliable; the network provider may not support provide cell tower triangulation capabilities to augment GPS, or Wifi triangulation capabilities. Other approaches to divine the device's location may not have a sufficient level of assurance to meet the organization's needs; for example, reverse IP lookups to determine a geographic location may be insufficiently granular, or may be masked by proxies designed to mask the true network origin of the user's device.

In these cases, an organization seeking to evaluate the riskiness of a transaction may require additional data to provide them with additional assurance that an individual is located in a specific geographic area to drive authentication decisions.

Another challenge for organizations deploying authentication is to match the "strength" of the authentication mechanism to the inherent risks presented by a particular user's environment (location, device, software, operating system), the request being made by the user or device (a request for access to restricted information, or to undertake a particular operation), and the governance policies of the organization.

To date, organizations have had to rely on a fairly static response to the authentication needs of its users: the organization evaluates the risks a user will face during operations they normally perform and the requirements of any applicable regulatory mandate, and then deploys an authentication solution to defend against that risk and achieve compliance. This usually requires the organization to deploy multiple authentication solutions to address the multitude

and variety of risks that their different users may face, which can be especially costly and cumbersome to manage.

The techniques described in the Co-pending applications provide an abstraction that allows the organization to identify existing capabilities on the user's device that can be used for authentication. This abstraction shields an organization from the need to deploy a variety of different authentication solutions. However, the organization still needs a way to invoke the "correct" authentication mechanism when necessary. Existing implementations provide no capabilities for the organization to describe what authentication mechanism is appropriate under which circumstances. As a result, an organization would likely need to codify their authentication policy in code, making the solution brittle and necessitating code changes in the future to enable use of new authentication devices/tokens.

## BRIEF DESCRIPTION OF THE DRAWINGS

A better understanding of the present invention can be obtained from the following detailed description in conjunction with the following drawings, in which:

FIG. **1** illustrates an exemplary client equipped with a biometric device;

FIG. **2** illustrates one embodiment of a system for performing location-aware application of authentication policy;

FIG. **3** illustrates an exemplary set of authentication policy rules;

FIG. **4** illustrates a method in accordance with one embodiment of the invention;

FIG. **5** illustrates one embodiment of the invention in which location is determined or confirmed by proximity of other peer or network devices;

FIG. **6** illustrates one embodiment of a system for authentication which uses environmental sensors;

FIG. **7** illustrates one embodiment of a method for authentication which uses environmental sensors;

FIG. **8** illustrates one embodiment of a system for adaptively applying an authentication policy;

FIG. **9** illustrates one embodiment of a method for adaptively applying an authentication policy; and

FIGS. **10**A-B illustrate exemplary system architectures on which the embodiments of the invention may be implemented.

## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Described below are embodiments of an apparatus, method, and machine-readable medium for implementing a location-aware authentication policy. Throughout the description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent, however, to one skilled in the art that the present invention may be practiced without some of these specific details. In other instances, well-known structures and devices are not shown or are shown in a block diagram form to avoid obscuring the underlying principles of the present invention.

The embodiments of the invention discussed below involve client devices with authentication capabilities such as biometric devices or PIN entry. These devices are sometimes referred to herein as "tokens," "authentication devices," or "authenticators." Various different biometric devices may be used including, but not limited to, fingerprint sensors, voice recognition hardware/software (e.g., a microphone and associated software for recognizing a user's voice), facial recognition hardware/software (e.g., a camera and associated software for recognizing a user's face), and optical recognition capabilities (e.g., an optical scanner and associated software for scanning the retina of a user). The authentication capabilities may also include non-biometric devices such as trusted platform modules (TPMs) smartcards, Trusted Execution Environments (TEEs), and Secure Elements (SEs)

As mentioned above, in a mobile biometric implementation, the biometric device may be remote from the relying party. As used herein, the "relying party" is the entity which utilizes the authentication techniques described herein to authenticate the end user. For example, the relying party may be an online financial service, online retail service (e.g., Amazon®), cloud service, or other type of network service with which the user is attempting to complete a transaction (e.g., transferring funds, making a purchase, accessing data, etc). In addition, as used herein, the term "remote" means that the biometric sensor is not part of the security boundary of the computer it is communicatively coupled to (e.g., it is not embedded into the same physical enclosure as the relying party computer). By way of example, the biometric device may be coupled to the relying party via a network (e.g., the Internet, a wireless network link, etc) or via a peripheral input such as a USB port. Under these conditions, there may be no way for the relying party to know if the device is one which is authorized by the relying party (e.g., one which provides an acceptable level of authentication and integrity protection) and/or whether a hacker has compromised the biometric device. Confidence in the biometric device depends on the particular implementation of the device.

### Location-Aware Authentication Techniques

One embodiment of the invention implements an authentication policy that allows authentication mechanisms to be selected based on the physical location of the client device being used for authentication. For example, the client and/or server may make a determination of the physical location of the client device, and feed that location to a policy engine that evaluates an ordered set of policy rules. In one embodiment, these rules specify classes of locations and the authentication mechanism or mechanisms that must be applied if the client location matches the location definition in the rule.

As illustrated in FIG. **2**, one embodiment of the invention includes a client device **200** with an authentication policy engine **210** for implementing the location-aware authentication policies described herein. In particular, this embodiment includes a location class determination module **240** for using the current location of the client device **200**, provided by location sensors **241** (e.g., a GPS device), to identify a current location "class." As discussed in detail below, different location "classes" may be defined comprising known geographical points and/or regions. Location class data may be continuously updated and stored in a persistent location data storage device **245** (e.g., a flash storage or other persistent storage device). The location class determination module **240** may then compare the current location provided by the sensor(s) **241** against the defined "classes" to determine a current location class for the client device **200**.

In one embodiment, the relying party **250** specifies the authentication policy to be implemented by the authentication policy engine **210** for each transaction (as indicated by the dotted line from the relying party to the authentication policy engine). Thus, the authentication policy may be uniquely tailored to the authentication requirements of each

relying party. In addition, the level of authentication required may be determined based on the current transaction (as defined by the authentication policy). For example, a transaction which requires a transfer of a significant amount of money may require a relatively high authentication assurance threshold, whereas non-monetary transaction may require a relatively lower authentication assurance threshold. Thus, the location-aware authentication techniques described herein may be sufficient for certain transactions but may be combined with more rigorous authentication techniques for other transactions.

In one embodiment, the location class determination module **240** provides the determined class to an authentication policy module **211** which implements a set of rules to identify the authentication techniques **212** to be used for the determined class. By way of example, and not limitation, FIG. **3** illustrates an exemplary set of rules 1-5 specifying one or more authentication techniques 1-5 which may be used for each defined location class 1-5. Although illustrated as a table data structure in FIG. **3**, the underlying principles of the invention are not limited to any particular type of data structure for implementing the rule set.

Once the authentication policy engine **210** selects a set of authentication techniques **212**, the authentication policy engine **210** may implement the techniques using one or more explicit user authentication devices **220-221** and/or non-intrusive authentication techniques **242-243** to authenticate the user with a relying party **250**. By way of example, and not limitation, the explicit user authentication **220-221** may include requiring the user to enter a secret code such as a PIN, fingerprint authentication, voice or facial recognition, and retinal scanning, to name a few.

The non-intrusive authentication techniques **242-243** may include user behavior sensors **242** which collect data related to user behavior for authenticating the user. For example, the biometric gait of the user may be measured using an accelerometer or other type of sensor **242** in combination with software and/or hardware designed to generate a gait "fingerprint" of the user's normal walking pattern. As discussed below, other sensors **243** may be used to collect data used for authentication. For example, network data may be collected identifying network/computing devices within the local proximity of the client device **200** (e.g., known peer computers, access points, cell towers, etc).

In one embodiment, secure storage **225** is a secure storage device used to store authentication keys associated with each of the authentication devices **220-221**. As discussed below, the authentication keys may be used to establish secure communication channels with the relying party **250** via a secure communication module **213**.

Various different "classes" of locations may be defined consistent with the underlying principles of the invention. By way of example, and not limitation, the following classes of locations may be defined:

Class 1: The client is within a given radius of a specified location. In this class, the associated authentication policy is applied if the current client location is within an area bounded by a circle of a given radius, centered at a specified latitude and longitude.

Class 2: The client is within a specified boundary region. In this class, the associated authentication policy is applied if the client is located within an area bounded by a polygon defined by an ordered set of latitude and longitude pairs (e.g., a closed polygon).

Class 3: The client is outside a specified boundary. In this class, the associated authentication policy is applied if the client is located outside an area bounded by a polygon defined by an ordered set of latitude and longitude pairs (e.g., a closed polygon).

In one embodiment, additional classes are defined using Boolean combinations of the classes and policy rules defined above. For example, the Boolean operations AND, OR, NOT, and the nesting of Boolean operations allow the expression of complex conditions. Such policies could be used, for example, to implement a policy that applies when the client is located in one of a variety of facilities owned by a company.

Various different mechanisms may be used to determine the current physical location of the client (represented generally in FIG. **2** as location sensors **241**), including, but not limited to the following:

GPS: Embedded GPS sensors can directly provide details on the location of the client. New emerging standards seek to add authentication of the location provided as a capability that address this shortcoming in current GPS solutions.

Geo-IP Lookup: Reverse lookups of the client's IP address can be used to determine a coarse approximation of the client's location. However, the trustworthiness of the location obtained through this method requires the IP address to be cross-checked against blacklists of known compromised hosts, anonymizing proxy providers, or similar solutions designed to obfuscate the source IP address of the host.

Cell Tower Triangulation: Integration between the client, the server, and wireless carrier infrastructure could allow the client and server to perform high resolution determination of physical location using cellular signal strength triangulation.

Wi-Fi Access Point Triangulation: A higher resolution method to determine physical location is to triangulate the signal strength of nearby Wifi access points with known physical locations. This method is particularly effective in determining the location of a device within facilities.

Location Displacement Inference: A device's exact location may be unknown, but a statistical probability of location may be used as an approximation for the purpose of evaluating policy. This may be calculated by noting the change in the device's position relative to a starting point with a known location; the user's device may have, in the past, had a known starting point, and in the interim has moved a known or estimate distance and bearing, allowing an approximate location to be calculated. Possible methods to calculate the displacement from the starting point may include inferring distance travelled using measurements gathered from an accelerometer (i.e. using the accelerometer to measure how far the user walked based on gait measurement), changes in signal strength from a known, stationary set of signal sources, and other methods.

FIG. **4** illustrates one embodiment of a method for implementing a location-aware authentication policy. The method may be executed within the context of the system architecture shown in FIGS. **2-3** but is not limited to any particular system architecture.

At **401** the client's location is identified using one or more available techniques (e.g., GPS, triangulation, peer/network device detection, etc). At **402**, one or more location classes (and potentially Boolean combinations of classes) are identified for the current location based on an existing set of policy rules. At **403**, one or more authentication techniques are identified according to the location class(es). For example, if the client device is currently at a location known to be the user's home or office or within a defined radius of another trusted location, then minimal (or no) authentication may be required. By contrast, if the client device is currently

at an unknown location and/or a location known to be untrusted, then more rigorous authentication may be required (e.g., biometric authentication such as a fingerprint scan, PIN entry, etc). At **404**, the authentication techniques are employed and if authentication is successful, determined at **405**, then the transaction requiring authentication is authorized at **406**.

As mentioned above, the level of authentication required may be determined based on the current transaction. For example, a transaction which requires a transfer of a significant amount of money may require a relatively high authentication assurance threshold, whereas non-monetary transaction may require a relatively lower authentication assurance threshold. Thus, the location-aware authentication techniques described herein may be sufficient for certain transactions but may be combined with more rigorous authentication techniques for other transactions.

If authentication is not successful, then the transaction is blocked at **407**. At this stage, the transaction may be permanently blocked or additional authentication steps may be requested. For example, if the user entered an incorrect PIN, the user may be asked to re-enter the PIN and/or perform biometric authentication.

The embodiments of the invention described herein provide numerous benefits to authentication systems. For example, the described embodiments may be used to efficiently block access from unauthorized locations, reducing unauthorized access by limiting the location from which users are permitted to attempt authentication (e.g., as defined by location classes). In addition, the embodiments of the invention may selectively require stronger authentication to respond to location-specific risks. For example, the relying party can minimize the inconvenience of authentication when a user is entering into a transaction from a known location, while retaining the ability to require stronger authentication when the user/client is connecting from an unknown or unexpected location. Moreover, the embodiments of the invention enable location-aware access to information. Alternatively, a location-centric policy may be used by a relying party to provide a user with additional access to location-specific information. By way of example, and not limitation, a user located in a Walmart may be granted access to special offers from Amazon.com when the user logs into their Amazon.com account on their mobile phone.

As mentioned above, the location of the client device **200** may be determined using a variety of different techniques. In one particular embodiment, the definition of a "location" may not be tied to a set of physical coordinates (as with GPS), but instead be prescribed by the presence of a set of peer devices or other types of network devices. For example, when at work, the client's wireless network adapters (e.g., Wifi adapter, Bluetooth adapter, LTE adapter, etc) may "see" a set of peer network devices (e.g., other computers, mobile phones, tablets, etc) and network infrastructure devices (e.g., Wifi access points, cell towers, etc) on a consistent basis. Thus, the presence of these devices may be used for authentication when the user is at work. Other locations may be defined by the presence of devices in a similar manner such as when the user is at home.

For example, using the techniques described herein, a location may be defined as "with my work colleagues" or "at work" where the presence of a set of peer devices known to be owned by the user's work colleagues may be used as a proxy for the risk that needs to be mitigated by authentication policy. For example, if a user is surrounded by a set of known peer devices or other types of network devices, then the user may be deemed to be less of a risk than if no known devices are detected.

FIG. **5** illustrates one embodiment in which a "location" is defined by a set of peer devices and other network devices. In the illustrated example, the client device **200** "sees" two different peer devices **505-506** (e.g., client computers, mobile phones, tablets, etc); two different wireless access points **510-511**; and two different cell towers **520-521**. As used herein, the client device **200** may "see" without formally establishing a connection with each of the other devices. For example, the client may see a variety of peer devices connected to the work LAN and/or may see the wireless signals generated by those devices regardless of whether the client connects to those devices. Similarly, the client device **200** may see the basic service set identification (BSSID) for a variety of different Wifi access points (e.g., Wifi from nearby hotels, coffee shops, work Wifi access points). The client device **200** may also see a variety of different cell towers **520-521**, potentially even those operated by different cell carriers. The presence of these devices may be used to define a location "fingerprint" for the user's work location.

As illustrated, device proximity detection logic **501** on the client device **200** may capture data related to visible devices and compare the results against historical device proximity data **504**. The historical device proximity data **504** may be generated over time and/or through a training process. For example, in one embodiment, the user may specify when he/she is at work, at home, or at other locations (either manually, or when prompted to do so by the client **200**). In response, the device proximity detection logic **501** may detect the devices in the vicinity and persistently store the results as historical device proximity data **504**. When the user subsequently returns to the location, the device proximity detection logic **501** may compare the devices that it currently "sees" against the devices stored as historical proximity data **504** to generate a correlation between the two. In general, the stronger the correlation, the more likely it is that the client is at the specified location. Over time, devices which are seen regularly may be prioritized above other devices in the historical device proximity data **504** (e.g., because these devices tend to provide a more accurate correlation with the user's work location).

In one embodiment, the authentication policy engine **210** may use the correlation results provided by the device proximity detection logic **501** to determine the level of authentication required by the user for each relying party **250**. For example, if a high correlation exists (i.e., above a specified threshold), then the authentication policy engine may not require explicit authentication by the end user. By contrast, if there is a low correlation between the user's current location and the historical device proximity data **504** (i.e., below a specified threshold), then the authentication policy engine **210** may require more rigorous authentication (e.g., a biometric authentication such as a fingerprint scan and/or requesting PIN entry).

In one embodiment, the device proximity detection logic **501** identifies the set of other devices that are in the client's proximity which have been authenticated. For example, if several of a user's colleagues have already authenticated successfully, then there may be less risk associated with allowing the user to access certain data with a less reliable authenticator, simply because the user is operating in the presence of his/her peers. In this embodiment, peer-to-peer communication over standards such as 802.11n may be used

to collect authentication tokens from peers that can be used to prove those peers have already authenticated.

In another embodiment, the device proximity detection logic **501** may also detect a previously authenticated device that is paired with the user's client (e.g., such as the user's mobile phone or tablet). The presence of another authenticated device that is used by the same user that is attempting to authenticate may be used as an input to the authentication decision, particularly when accessing the same application.

In one embodiment, the historical device proximity data **504** is collected and shared across multiple devices, and may be stored and maintained on an intermediate authentication service. For example, a history of groups of peers and network devices in each location may be tracked and stored in a central database accessible to the device proximity detection logic **501** on each device. This database may then be used as an input to determine the risk of an attempted authentication from a particular location.

## Embodiments for Confirming Location Using Supplemental Sensor and/or Location Data

As mentioned above, one embodiment of the invention leverages data from additional sensors **243** from the mobile device to provide supplemental inputs to the risk calculation used for authentication. These supplemental inputs may provide additional levels of assurance that can help to either confirm or refute claims of the location of the end user's device.

As illustrated in FIG. **6** the additional sensors **243** which provide supplemental assurance of the device's location may include temperature sensors **601**, humidity sensors **602** and pressure sensors **603** (e.g., barometric or altimeter pressure sensors). In one embodiment, the sensors provide temperature, humidity, and pressure readings, respectively, which are used by a supplemental data correlation module **640** of the authentication policy engine **210** to correlate against supplemental data **610** known about the location provided by the location sensor(s) **241** (or the location derived using the various other techniques described herein). The results of the correlation are then used by the authentication policy module **211** to select one or more authentication techniques **212** for a given transaction. As indicated in FIG. **6**, the supplemental location data **610** may include data collected from external sources (e.g., the Internet or other mobile devices) and local data sources (e.g., historical data collected during periods when the device is known to be in possession of the legitimate user).

The supplemental data correlation module **640** may use the data provided by the additional sensors **243** in a variety of different ways to correlate against the supplemental location data **610**. For example, in one embodiment, the supplemental location data **610** includes current local meteorological conditions at the location provided by the location sensor(s) **241**. By comparing the humidity, temperature, or barometric pressure gathered from the additional sensors **243** against real-time local weather data **610**, the supplemental data correlation module **640** identifies cases where the sensor data is inconsistent with local conditions. For example, if the client device's GPS reading indicates that the device is outside, yet the temperature, humidity, or barometric pressure are not consistent with the local weather conditions, then the supplemental data correlation module **640** may generate a low correlation score and the location may be deemed less trustworthy. Consequently, the authentication policy module **211** may require more rigorous authentication techniques **212** (e.g., fingerprint, PIN entry, etc) to approve a transaction.

As another example, by comparing the altitude provided by an altimeter pressure sensor **603** against the known geographical or network topology of the claimed location (provided with the supplemental location data **610**), the supplemental data correlation module **640** may identify discrepancies that signal the claimed location is not genuine. For example, if a reverse IP lookup of the user's claimed location identifies them as being in the Andes Mountains, but altimeter data from the device indicates the device is at sea level, then the supplemental data correlation module **640** may generate a low correlation score and the location may be deemed less trustworthy. As a result of the low correlation score, the authentication policy module **211** may attempt to mitigate the higher risk with stronger authentication for the transaction.

In one embodiment, the supplemental data correlation module **640** compares data gathered from sensors **243** on the user's device against multiple other end users in the immediate area to identify anomalies that suggest the user is not operating in the same physical location as those known users. For example, if a set of authenticated users are identified who are operating the same physical area, and all of those users' devices note that the local temperature in the area is 10° C., the supplemental data correlation module **640** may generate a low correlation score for an end user whose temperature sensor **601** indicates the local temperature is 20° C. As a result, the authentication policy **211** may require more rigorous authentication techniques **212**.

As yet another example, the supplemental data correlation module **640** may compare current readings against historical data for a particular user. For example, as mentioned, sensor data may be analyzed during periods of time when the user is known to be in possession of the device **200** (e.g., for a time period following an explicit authentication). The supplemental data correlation module **640** may then look for discontinuities in the local data to identify suspicious behavior. For example, if the user's ambient temperature normally floats between 10° C. and 20° C. and it is currently at 30° C., this may indicate the user is not in a typical location, thereby generating a low correlation and causing the authentication policy module **211** to require an additional level of scrutiny for a transaction.

The supplemental data correlation module **640** may perform various different types of correlations between sensor data and supplemental location data while still complying with the underlying principles of the invention. For example, various known correlation mechanisms may be used to determine the statistical relationship between the two sets of data. In one embodiment, the correlation score provided to the authentication policy engine **211** comprises a normalized value (e.g., between 0-1) indicating a level of correlation. In one embodiment, various threshold levels may be set for detected differences between the sensors **243** and supplemental location data **610**. For example, if the temperature sensor **601** measures a temperature of more than 3 degrees off of the current temperature (gathered from other devices or the Internet), then a first threshold may be triggered (resulting in a lowering of the correlation score). Each additional 3 degrees off from the current temperature may then result in a new threshold being met (resulting in a corresponding lowering of the correlation score). It should be noted, however, that these are merely examples of one

embodiment of the invention; the underlying principles of the invention are not limited to any particular manner of performing a correlation.

A method in accordance with one embodiment of the invention is illustrated in FIG. **7**. At **701**, the current location being reported by the client device (e.g., via the GPS module on the device) is read. At **702**, supplemental location data is collected for the reported location along with sensor data from the client device. As mentioned above, the supplemental location data may be collected locally or remotely (e.g., from other clients and/or servers on the Internet) and may include data such as the current temperature, pressure and/or humidity for the reported location. The sensor data may be provided by temperature sensors, barometric or altimeter pressure sensors, and/or humidity sensors.

At **703**, a correlation is performed between the supplemental location data and the sensor data provided by the device sensors. In one embodiment, a relatively higher correlation will result in a relatively higher correlation score at **704** whereas lower correlations will result in relatively lower correlation scores. As mentioned, in one embodiment, the correlation score is a normalized value (e.g., between 0-1) indicating the similarity between the sensor readings and supplemental data.

At **705** one or more authentication techniques are selected based (at least in part) on the correlation score. For example, if a relatively low correlation score is provided, then more rigorous authentication techniques may be selected whereas if a relatively high correlation exists then less rigorous authentication techniques may be selected (potentially those which do not require explicit authentication by the end user).

If the user successfully authenticates using the selected techniques, determined at **706**, then the transaction is allowed to proceed at **707**. If not, then the transaction is blocked at **708**.

Numerous benefits are realized from the above embodiments. For example, these embodiments provide an additional level of assurance for location data gather from other sources: Allows the organization to supplement location data gathered from other sources (IP, GPS, etc) in order to gain additional assurance that the location is authentic. In addition, the embodiments of the invention may block a transaction from an unauthorized location, reducing unauthorized access by limiting the location from which users can even attempt authentication. Moreover, these embodiments may force stronger authentication to respond to location-specific risks (e.g., the relying party can minimize the inconvenience of authentication when the user is accessing information from a known location, while retaining the ability to require stronger authentication when the user/client is accessing from an unknown or unexpected location, or a location whose veracity can't be sufficiently qualified using multiple inputs).

## Adaptive Application of Authentication Policy Based on Client Authentication Capabilities

As illustrated in FIG. **8**, one embodiment of the invention includes an adaptive authentication policy engine **845** that allows an organization—e.g., a relying party with secure transaction services **250** (hereinafter simply referred to as the "relying party")—to specify which types of authentication are appropriate for a particular class of interactions. As illustrated, the adaptive authentication policy engine **845** may be implemented as a module within the authentication engine **811** executed at the relying party **250**. In this embodiment, the adaptive authentication policy engine **845** executes in accordance with a policy database **825** containing data for existing authentication devices **829**, authentication device classes **828**, interaction classes **827**, and authentication rules **826**.

In one embodiment, the authentication device data **829** comprises data associated with each of the explicit user authentication devices **220-221** known to be used with clients **200**. For example, the policy database **825** may include an entry for a "Validity Model 123" fingerprint sensor along with technical details related to this sensor such as the manner in which the sensor stores sensitive data (e.g., in cryptographically secure hardware, EAL 3 certification, etc) and the false acceptance rate (indicating how reliable the sensor is when generating a user authentication result).

In one embodiment, the authentication device classes **828** specify logical groupings of authentication devices **829** based on the capabilities of those devices. For example, one particular authentication device class **828** may be defined for (1) fingerprint sensors (2) that store sensitive data in cryptographically secure hardware that has been EAL 3 certified, and (3) that use a biometric matching process with a false acceptance rate less than 1 in 1000. Another device class **828** may be (1) facial recognition devices (2) which do not store sensitive data in cryptographically secure hardware, and (3) that use a biometric matching process with a false acceptance rate less than 1 in 500. Thus, a fingerprint sensor or facial recognition implementation which meets the above criteria will be added to the appropriate authentication device class(es) **828**.

Various individual attributes may be used to define authentication device classes, such as the type of authentication factor (fingerprint, PIN, face, for example), the level of security assurance of the hardware, the location of storage of secrets, the location where cryptographic operations are performed by the authenticator (e.g., in a secure chip or Secure Enclosure), and a variety of other attributes. Another set of attributes which may be used are related to the location on the client where the "matching" operations are performed. For example, a fingerprint sensor may implement the capture and storage of fingerprint templates in a secure storage on the fingerprint sensor itself, and perform all validation against those templates within the fingerprint sensor hardware itself, resulting in a highly secure environment. Alternatively, the fingerprint sensor may simply be a peripheral that captures images of a fingerprint, but uses software on the main CPU to perform all capture, storage, and comparison operations, resulting in a less secure environment. Various other attributes associated with the "matching" implementation may also be used to define the authentication device classes (e.g., whether the matching is (or is not) performed in a secure element, trusted execution environment (TEE)), or other form of secure execution environment).

Of course, these are merely examples for illustrating the concept of authentication device classes. Various additional authentication device classes may be specified while still complying with the underlying principles. Moreover, it should be noted that, depending on how the authentication device classes are defined, a single authentication device may be categorized into multiple device classes.

In one embodiment, the policy database **825** may be updated periodically to include data for new authentication devices **829** as they come to market as well as new authentication device classes **828**, potentially containing new classes into which the new authentication devices **829** may be classified. The updates may be performed by the relying party and/or by a third party responsible for providing the

updates for the relying party (e.g., a third party who sells the secure transaction server platforms used by the relying party).

In one embodiment, interaction classes **827** are defined based on the particular transactions offered by the relying party **825**. For example, if the relying party is a financial institution, then interactions may be categorized according to the monetary value of the transaction. A "high value interaction" may be defined as one in which an amount of $5000 or more is involved (e.g., transferred, withdrawn, etc); a "medium value interaction" may be defined as one in which an amount between $500 and $4999 is involved; and a "low value transaction" may be defined as one in which an amount of $499 or less is involved.

In addition to the amount of money involved, interaction classes may be defined based on the sensitivity of the data involved. For example, transactions disclosing a user's confidential or otherwise private data may be classified as "confidential disclosure interactions" whereas those which do not disclose such data may be defined as "non-confidential disclosure interactions." Various other types of interactions may be defined using different variables and a variety of minimum, maximum, and intermediate levels.

Finally, a set of authentication rules **826** may be defined which involve the authentication devices **829**, authentication device classes **827**, and/or interaction classes **827**. By way of example, and not limitation, a particular authentication rule may specify that for "high value transactions" (as specified by an interaction class **827**) only fingerprint sensors that store sensitive data in cryptographically secure hardware that has been EAL 3 certified, and that use a biometric matching process with a false acceptance rate less than 1 in 1000 (as specified as an authentication device class **828**) may be used. If a fingerprint device is not available, the authentication rule may define other authentication parameters that are acceptable. For example, the user may be required to enter a PIN or password and also to answer a series of personal questions (e.g., previously provided by the user to the relying party). Any of the above individual attributes specified for authentication devices and/or authentication device classes may be used to define the rules, such as the type of authentication factor (fingerprint, PIN, face, for example), the level of security assurance of the hardware, the location of storage of secrets, the location where cryptographic operations are performed by the authenticator.

Alternatively, or in addition, a rule may specify that certain attributes can take on any value, as long as the other values are sufficient. For example, the relying party may specify that a fingerprint device must be used which stores its seed in hardware and performs computations in hardware, but does not care about the assurance level of the hardware (as defined by an authentication device class **828** containing a list of authentication devices meeting these parameters).

Moreover, in one embodiment, a rule may simply specify that only specific authentication devices **829** can be used for authenticating a particular type of interaction. For example, the organization can specify that only a "Validity Model 123 fingerprint sensor" is acceptable.

In addition, a rule or set of rules may be used to create ordered, ranked combinations of authentication policies for an interaction. For example, the rules may specify combinations of policies for individual authentication policies, allowing the creation of rich policies that accurate reflect the authentication preferences of the relying party. This would allow, for example, the relying party to specify that fingerprint sensors are preferred, but if none is available, then either trusted platform module (TPM)-based authentication or face recognition are equally preferable as the next best alternatives (e.g., in a prioritized order).

In one embodiment, the adaptive authentication policy engine **845** implements the authentication rules **826**, relying on the interaction classes **827**, authentication device classes **828**, and/or authentication device data **829**, when determining whether to permit a transaction with the client **200**. For example, in response to the user of the client device **200** attempting to enter into a transaction with the relying party website or other online service **846**, the adaptive authentication policy engine **845** may identify a set of one or more interaction classes **827** and associated authentication rules **826** which are applicable. It may then apply these rules via communication with an adaptive authentication policy module **850** on the client device **200** (illustrated in FIG. **8** as a component within the client's authentication engine **810**). The adaptive authentication policy module **850** may then identify a set of one or more authentication techniques **812** to comply with the specified authentication policy. For example, if a prioritized set of authentication techniques are specified by the adaptive authentication policy engine **845** of the relying party, then the adaptive authentication policy module **850** may select the highest priority authentication technique which is available on the client **200**.

The results of the authentication techniques **812** are provided to an assurance calculation module **840** which generates an assurance level that the current user is the legitimate user. In one embodiment, if the assurance level is sufficiently high, then the client will communicate the results of the successful authentication to the authentication engine **811** of the relying party, which will then permit the transaction.

In one embodiment, data from the client device sensors **241-243** may also be used by the assurance calculation module **840** to generate the assurance level. For example, the location sensor (e.g., a GPS device) may indicate a current location for the client device **200**. If the client device is in an expected location (e.g., home or work), then the assurance calculation module **840** may use this information to increase the assurance level. By contrast, if the client device **200** is in an unexpected location (e.g., a foreign country not previously visited by the user), then the assurance calculation module **840** may use this information to lower the assurance level (thereby requiring more rigorous explicit user authentication to reach an acceptable assurance level). As discussed above, various additional sensor data such as temperature, humidity, accelerometer data, etc, may be integrated into the assurance level calculation.

The system illustrated in FIG. **8** may operate differently based on specificity with which the client authentication capabilities and other information are communicated to the relying party. For example, in one embodiment, the specific models of each of the explicit user authentication devices **220-221** and specific details of the security hardware/software and sensors **241-243** on the client device **200** may be communicated to the relying party **250**. As such, in this embodiment, the adaptive authentication policy engine **845** may specifically identify the desired mode(s) of authentication, based on the authentication rules implemented for the current transaction and the risk associated with the client. For example, the adaptive authentication policy module **845** may request authentication via the "Validity Model 123" fingerprint sensor installed on the client for a given transaction.

In another embodiment, only a generic description of the authentication capabilities of the client device **200** may be provided to protect the user's privacy. For example, the

client device may communicate that it has a fingerprint sensor that stores sensitive data in a cryptographically secure hardware that has been EAL 3 certified and/or that uses a biometric matching process with a false acceptance rate less than 1 in N. It may specify similar generic information related to the capabilities and specifications of other authentication devices, without disclosing the specific models of those devices. The adaptive authentication policy engine **845** may then use this general information to categorize the authentication devices in applicable authentication device classes **838** within the database **825**. In response to a request to perform a transaction, the adaptive authentication policy module **845** may then instruct the client device **200** to use a particular authentication device if its class is sufficient to complete the transaction.

In yet another embodiment, the client device **200** does not communicate any data related to its authentication capabilities to the relying party. Rather, in this embodiment, the adaptive authentication policy module **845** communicates the level of authentication required and the adaptive authentication policy module **850** on the client selects one or more authentication techniques which meet that level of authentication. For example, the adaptive authentication policy module **845** may communicate that the current transaction is classified as a "high value transaction" (as specified by an interaction class **827**) for which only certain classes of authentication devices may be used. As mentioned, it may also communicate the authentication classes in a prioritized manner. Based on this information, the adaptive authentication policy module **850** on the client may then select one or more authentication techniques **812** required for the current transaction.

As indicated in FIG. **8**, the client device **200** may include its own policy database(s) **890** to store/cache policy data for each relying party. The policy database **890** may comprise a subset of the data stored within the policy database **825** of the relying party. In one embodiment, a different set of policy data is stored in the database **890** for each relying party (reflecting the different authentication policies of each relying party). In these embodiments, the mere indication of a particular category of transaction (e.g., a "high value transaction," "low value transaction", etc) may be sufficient information for the adaptive authentication policy module **850** on the client device **200** to select the necessary authentication techniques **812** (i.e., because the rules associated with the various transaction types are available within the local policy database **890**). As such, the adaptive authentication policy module **845** may simply indicate the interaction class of the current transaction, which the adaptive authentication policy module **850** uses to identify the authentication techniques **812** based on the rules associated with that interaction class.

A method for performing adaptive authentication based on client device capabilities is illustrated in FIG. **9**. The method may be implemented on the system illustrated in FIG. **8**, but is not limited to any particular system architecture.

At **901** a client attempts to perform a transaction with a relying party. By way of example, and not limitation, the client may enter payment information for an online purchase or attempt to transfer funds between bank accounts. At **902**, the transaction is categorized. For example, as discussed above, the transaction may be associated with a particular interaction class based on variables such as the amount of money involved or the sensitivity of information involved.

At **903**, one or more rules associated with the category of transaction are identified. Returning to the above example, if the transaction is categorized as a "high value transaction" then a rule associated with this transaction type may be selected. At **904**, the rule(s) associated with the transaction type are executed and, as discussed above, information is sent to the client indicating the authentication requirements to complete the transaction. As discussed above, this may involve identifying specific authentication devices, identifying classes of authentication devices, or merely indicating the particular rule which needs to be implemented (e.g., if the client maintains local copies of the rules).

In any case, at **905** a set of one or more authentication techniques are selected based on the requirements specified via the rule(s) and the authentication capabilities of the client. If authentication is successful, determined at **906**, then the transaction is permitted at **907**. If not, then the transaction is blocked at **908** (or additional authentication is requested from the user).

There are numerous benefits realized from the embodiments of the invention described herein. For example, these embodiments reduce the effort required to integrate authentication capabilities at the relying party. For example, instead of writing code to codify an authentication policy, rules can be configured through a simple graphical user interface. All the relying party needs to do to integrate is define a policy for a class of interactions (for example: "Large Money Transfers") and have the integration code use that policy identifier when interacting with the policy engine to determine the correct authentication mechanism to leverage.

Moreover, these embodiments simplify authentication policy administration. By expressing the authentication policy outside of code, this approach allows the organization to easily update their authentication policies without requiring code changes. Changes to reflect new interpretations of regulatory mandates, or respond to attacks on existing authentication mechanisms become a simple change in the policy, and can be effected quickly.

Finally, these embodiments allow for future refinement of authentication techniques. As new authentication devices become available, an organization can evaluate its appropriateness to addressing new or emerging risks. Integrating a newly available authentication device only requires adding the authentication device to a policy; no new code has to be written to deploy the new capability immediately.

## Exemplary System Architectures

It should be noted that the term "relying party" is used herein to refer, not merely to the entity with which a user transaction is attempted (e.g., a Website or online service performing user transactions), but also to the secure transaction servers implemented on behalf of that entity which may performed the underlying authentication techniques described herein. The secure transaction servers may be owned and/or under the control of the relying party or may be under the control of a third party offering secure transaction services to the relying party as part of a business arrangement. These distinctions are indicated in FIGS. **10**A-B discussed below which show that the "relying party" may include Websites **1031** and other network services **1051** as well as the secure transaction servers **1032-1033** for performing the authentication techniques on behalf of the websites and network services.

In particular, FIGS. **10**A-B illustrate two embodiments of a system architecture comprising client-side and server-side components for authenticating a user. The embodiment shown in FIG. **10**A uses a browser plugin-based architecture

for communicating with a website while the embodiment shown in FIG. **10**B does not require a browser. The various techniques described herein for adaptively implementing an authentication policy may be employed on either of these system architectures. For example, the authentication engine **811** at the relying party and local authentication engine **810** on the client in FIG. **8** may be implemented as part of the secure transaction service **1001** including interface **1002**. It should be noted, however, that the embodiment illustrated in FIG. **8** stands on its own and may be implemented using logical arrangements of hardware and software other than those shown in FIGS. **10**A-B.

Turning to FIG. **10**A, the illustrated embodiment includes a client **1000** equipped with one or more authentication devices **1010-1012** for enrolling and authenticating an end user. As mentioned above, the authentication devices **1010-1012** may include biometric devices such as fingerprint sensors, voice recognition hardware/software (e.g., a microphone and associated software for recognizing a user's voice), facial recognition hardware/software (e.g., a camera and associated software for recognizing a user's face), and optical recognition capabilities (e.g., an optical scanner and associated software for scanning the retina of a user) and non-biometric devices such as a trusted platform modules (TPMs) and smartcards. A user may enroll the biometric devices by providing biometric data (e.g., swiping a finger on the fingerprint device) which the secure transaction service **1001** may store as biometric template data in secure storage **1020** (via interface **1002**).

While the secure storage **1020** is illustrated outside of the secure perimeter of the authentication device(s) **1010-1012**, in one embodiment, each authentication device **1010-1012** may have its own integrated secure storage. Additionally, each authentication device **1010-1012** may cryptographically protect the biometric reference data records (e.g., wrapping them using a symmetric key to make the storage **1020** secure).

The authentication devices **1010-1012** are communicatively coupled to the client through an interface **1002** (e.g., an application programming interface or API) exposed by a secure transaction service **1001**. The secure transaction service **1001** is a secure application for communicating with one or more secure transaction servers **1032-1033** over a network and for interfacing with a secure transaction plugin **1005** executed within the context of a web browser **1004**. As illustrated, the Interface **1002** may also provide secure access to a secure storage device **1020** on the client **1000** which stores information related to each of the authentication devices **1010-1012** such as a device identification code, user identification code, user enrollment data (e.g., scanned fingerprint or other biometric data), and keys used to perform the secure authentication techniques described herein. For example, as discussed in detail below, a unique key may be stored into each of the authentication devices and used when communicating to servers **1030** over a network such as the Internet.

In addition to enrollment of devices, the secure transaction service **1001** may then register the biometric devices with the secure transaction servers **1032-1033** over the network and subsequently authenticate with those servers using data exchanged during the registration process (e.g., encryption keys provisioned into the biometric devices). The authentication process may include any of the authentication techniques described herein (e.g., generating an assurance level on the client **1000** based on explicit or non-intrusive authentication techniques and transmitting the results to the secure transaction servers **1032-1033**).

As discussed below, certain types of network transactions are supported by the secure transaction plugin **1005** such as HTTP or HTTPS transactions with websites **1031** or other servers. In one embodiment, the secure transaction plugin is initiated in response to specific HTML tags inserted into the HTML code of a web page by the web server **1031** within the secure enterprise or Web destination **1030** (sometimes simply referred to below as "server **1030**"). In response to detecting such a tag, the secure transaction plugin **1005** may forward transactions to the secure transaction service **1001** for processing. In addition, for certain types of transactions (e.g., such as secure key exchange) the secure transaction service **1001** may open a direct communication channel with the on-premises transaction server **1032** (i.e., co-located with the website) or with an off-premises transaction server **1033**.

The secure transaction servers **1032-1033** are coupled to a secure transaction database **1040** for storing user data, authentication device data, keys and other secure information needed to support the secure authentication transactions described below. It should be noted, however, that the underlying principles of the invention do not require the separation of logical components within the secure enterprise or web destination **1030** shown in FIG. **10**A. For example, the website **1031** and the secure transaction servers **1032-1033** may be implemented within a single physical server or separate physical servers. Moreover, the website **1031** and transaction servers **1032-1033** may be implemented within an integrated software module executed on one or more servers for performing the functions described below.

As mentioned above, the underlying principles of the invention are not limited to a browser-based architecture shown in FIG. **10**A. FIG. **10**B illustrates an alternate implementation in which a stand-alone application **1054** utilizes the functionality provided by the secure transaction service **1001** to authenticate a user over a network. In one embodiment, the application **1054** is designed to establish communication sessions with one or more network services **1051** which rely on the secure transaction servers **1032-1033** for performing the user/client authentication techniques described in detail below.

In either of the embodiments shown in FIGS. **10**A-B, the secure transaction servers **1032-1033** may generate the keys which are then securely transmitted to the secure transaction service **1001** and stored into the authentication devices within the secure storage **1020**. Additionally, the secure transaction servers **1032-1033** manage the secure transaction database **1040** on the server side.

Embodiments of the invention may include various steps as set forth above. The steps may be embodied in machine-executable instructions which cause a general-purpose or special-purpose processor to perform certain steps. Alternatively, these steps may be performed by specific hardware components that contain hardwired logic for performing the steps, or by any combination of programmed computer components and custom hardware components.

Elements of the present invention may also be provided as a machine-readable medium for storing the machine-executable program code. The machine-readable medium may include, but is not limited to, floppy diskettes, optical disks, CD-ROMs, and magneto-optical disks, ROMs, RAMs, EPROMs, EEPROMs, magnetic or optical cards, or other type of media/machine-readable medium suitable for storing electronic program code.

Throughout the foregoing description, for the purposes of explanation, numerous specific details were set forth in

order to provide a thorough understanding of the invention. It will be apparent, however, to one skilled in the art that the invention may be practiced without some of these specific details. For example, it will be readily apparent to those of skill in the art that the functional modules and methods described herein may be implemented as software, hardware or any combination thereof. Moreover, although some embodiments of the invention are described herein within the context of a mobile computing environment, the underlying principles of the invention are not limited to a mobile computing implementation. Virtually any type of client or peer data processing devices may be used in some embodiments including, for example, desktop or workstation computers. Accordingly, the scope and spirit of the invention should be judged in terms of the claims which follow.

I claim:

**1**. A method for user authentication comprising:

initially defining a plurality of authentication device classes based on characteristics of client authentication devices, the characteristics comprising a type of authentication device and a level of security assurance of the client device's hardware and/or software;

initially defining a plurality of interaction classes for a relying party, the interaction classes defined based on variables associated with interactions between a client and the relying party, the variables including an amount of money or a level of sensitivity of information involved in the interactions;

initially defining one or more authentication rule sets specifying authentication devices or classes of authentication devices to be used for different interaction classes, the one or more authentication rule sets comprising a first rule set;

detecting, by a secure transaction services engine, a user of a client attempting to perform a current interaction with a relying party over a network; and

responsively identifying a first interaction class for the current interaction, by an adaptive authentication policy hardware engine, based on variables associated with the current interaction and

implementing a first rule set of one or more authentication rules associated with the first interaction class to authenticate the user of the client, wherein implementing the first rule set of one or more authentication rules comprises the adaptive authentication policy hardware engine implementing a first rule specifying a particular authentication device class required to authenticate the user for the current interaction, wherein the first rule comprises a prioritized list of acceptable authentication device classes for the current interaction.

**2**. The method as in claim **1** further comprising:

initially classifying a plurality of authentication device models into the plurality of authentication device classes based on characteristics of the authentication device models.

**3**. The method as in claim **1** wherein the client selects a first authentication device to be used for authentication based on the prioritized list of acceptable authentication device classes.

**4**. The method as in claim **1** wherein the variables associated with the current interaction comprises an amount of money or sensitivity of data involved in the current interaction.

**5**. The method as in claim **1** wherein the type of authentication device includes fingerprint authentication, PIN or password entry, face recognition authentication, voice recognition authentication, authentication using a trusted platform module (TPM) device, and/or retinal scanning authentication.

**6**. The method as in claim **2** wherein at least one authentication device class is defined to have a particular authentication factor with a false acceptance rate below a specified threshold.

**7**. The method as in claim **2** wherein at least one authentication device class is defined based on where and/or how a matching algorithm is implemented to match biometric data extracted from an authentication device with biometric template data stored in a secure storage.

**8**. The method as in claim **7** wherein the authentication device class is defined based on the matching algorithm being, or not being implemented within a secure execution environment.

**9**. The method as in claim **6** wherein the one authentication device class is further defined to store sensitive data in cryptographically secure hardware and/or software.

**10**. The method as in claim **3** further comprising:

generating an assurance level based, at least in part, on a user authentication with the first authentication device.

**11**. The method as in claim **10** wherein the interaction is permitted if the assurance level is above a specified threshold.

**12**. The method as in claim **11** wherein the assurance level is generated, at least in part, based on current sensor data read from client sensors, wherein at least one of the sensors comprises a location sensor providing a current location of the client.

**13**. An authentication system comprising:

an authentication policy database to store authentication policies for a relying party;

a secure transaction services engine of the relying party to detect a user of a client attempting to perform a current interaction with the relying party over a network;

an adaptive authentication policy hardware engine of the relying party to perform operations of:

initially define a plurality of interaction classes in the authentication policy database, the interaction classes defined based on variables associated with interactions between the client and the relying party, the variables including an amount of money or a level of sensitivity of information involved in the interactions;

initially define one or more authentication rule sets in the authentication policy database specifying authentication devices or classes of authentication devices to be used for different interaction classes, the one or more authentication rule sets comprising a first rule set; and

query the authentication policy database to identify a first interaction class for the current interaction based on variables associated with the current interaction and to implement the first rule set of one or more authentication rules associated with the first interaction class to authenticate the user of the client, wherein implementing a first rule set of one or more authentication rules comprises the adaptive authentication policy hardware engine implementing a first rule specifying a particular authentication device class required to authenticate the user for the current interaction, the first rule comprising a prioritized list of acceptable authentication device classes for the current interaction, and wherein the adaptive authentication policy hardware engine is to perform additional operations of initially defining a plurality of

authentication device classes in the authentication policy database based on characteristics of client authentication devices, the characteristics comprising a type of authentication device and a level of security assurance of the client device's hardware and/or software.

**14**. The authentication system as in claim **13** further comprising:

initially classifying a plurality of authentication device models into the plurality of authentication device classes in the authentication policy database based on characteristics of the authentication device models.

**15**. The authentication system as in claim **13** wherein the client selects a first authentication device to be used for authentication based on the prioritized list of acceptable authentication device classes.

**16**. The authentication system as in claim **13** wherein the variables associated with the current interaction comprises an amount of money or sensitivity of data involved in the current interaction.

**17**. The authentication system as in claim **13** wherein the type of authentication device includes fingerprint authentication, PIN or password entry, face recognition authentication, voice recognition authentication, authentication using a trusted platform module (TPM) device, and/or retinal scanning authentication.

**18**. The authentication system as in claim **14** wherein at least one authentication device class is defined to have a particular authentication factor with a false acceptance rate below a specified threshold.

**19**. The authentication system as in claim **14** wherein at least one authentication device class is defined based on where and/or how a matching algorithm is implemented to match biometric data extracted from an authentication device with biometric template data stored in a secure storage.

**20**. The authentication system as in claim **19** wherein the authentication device class is defined based on the matching algorithm being, or not being implemented within a secure execution environment.

**21**. The authentication system as in claim **18** wherein the one authentication device class is further defined to store sensitive data in cryptographically secure hardware and/or software.

**22**. The authentication system as in claim **15** further comprising:

the client generating an assurance level based, at least in part, on a user authentication with the first authentication device.

**23**. The authentication system as in claim **22** wherein the interaction is permitted if the assurance level is above a specified threshold.

**24**. The authentication system as in claim **23** wherein the assurance level is generated, at least in part, based on current sensor data read from client sensors, wherein at least one of the sensors comprises a location sensor providing a current location of the client.

**25**. The method as in claim **1**, wherein the characteristics of client authentication devices further comprises a type of location in which secrets are stored.

**26**. The method as in claim **1**, wherein the characteristics of client authentication devices further comprises a type of location where cryptographic operations are performed by the authentication devices.

**27**. The authentication system as in claim **13**, wherein the characteristics of client authentication devices further comprises a type of location in which secrets are stored.

**28**. The authentication system as in claim **13**, wherein the characteristics of client authentication devices further comprises a type of location where cryptographic operations are performed by the authentication devices.

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